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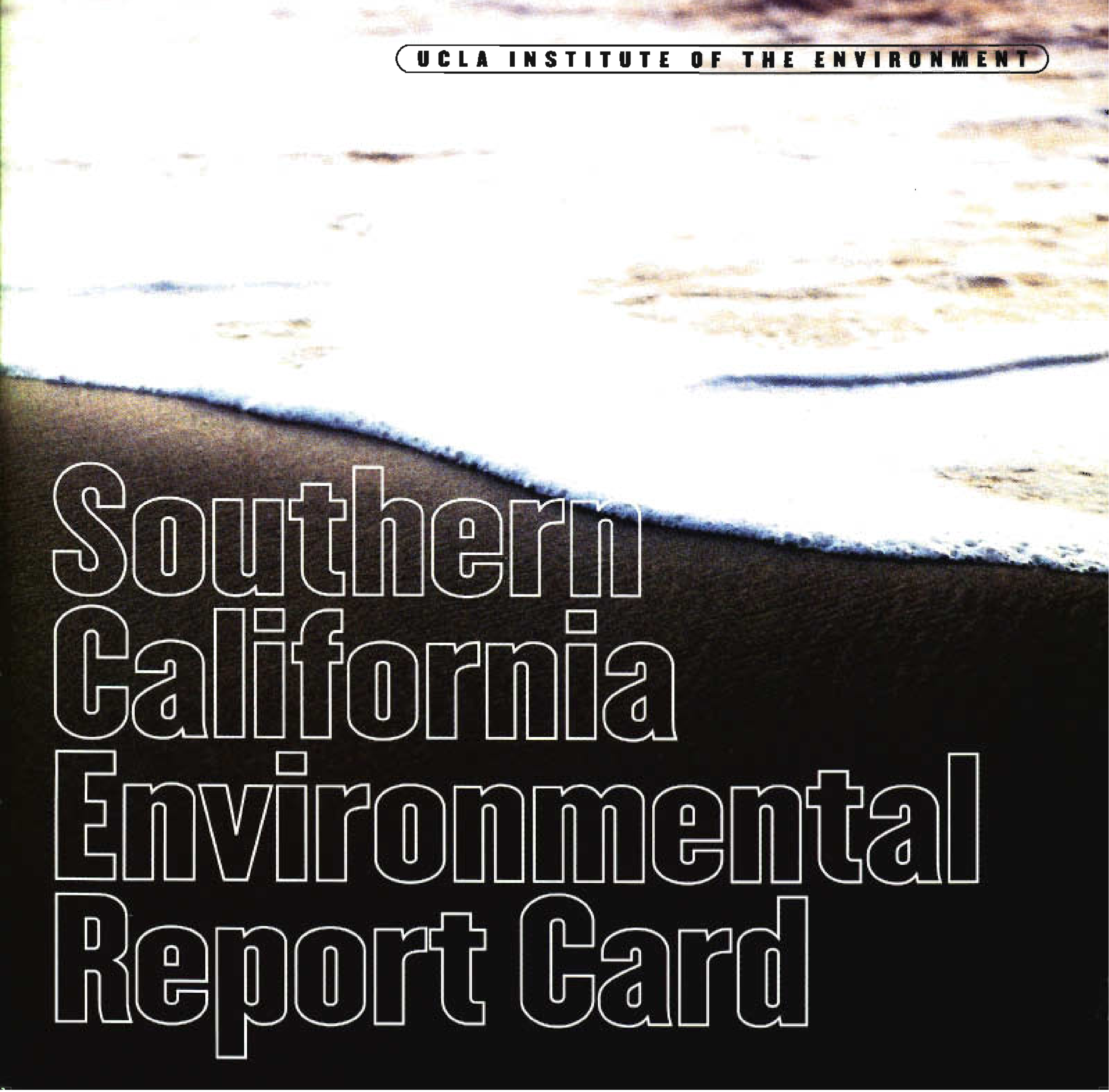

Southern California Environmental Report Card

1998 Southern California Environmental Report Card

UCLA Institute of the Environment

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GRADE Inland Plants: A / Coastal Plants: C

Wastewater Treatment

by Michael K. Stenstrom, Ph.D., P.E.

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Introduction

Southern California encompasses more than 1,000 square miles and approximately 11 million people. Water is scarce, with annual rainfall averaging about 12 inches/year in the Los Angeles basin, more in the small mountains surrounding Los Angeles, and much less in the deserts to the east. Drinking water and water for agriculture and irrigation are imported from Northern California, the Colorado River and the Sierra Mountains. There is always interest in water conservation and reclamation, especially in drought years, such as the recently ended drought spanning 1985 to 1993.

Wastewater treatment is a continuing concern especially for ocean communities and the ecological health of our fisheries. Only recently have Los Angeles County and the City of Los Angeles committed themselves to providing full secondary treatment in coastal locations. Other coastal areas, such as Orange County and San Diego County, still have ocean waivers for their coastal plants. This allows them to use less efficient and expensive treatment, such as primary or advanced primary treatment, and discharge these partially treated wastewaters through ocean outfalls or diffusers. Inland areas, such as Whittier Narrows and Chino Basin, have wastewater-treatment systems that are more advanced than secondary treatment, and much of the treated wastewater (effluent) is reclaimed.

This discussion provides background on wastewater and treatment systems. Our objective is to inform the reader about the need for and types of wastewater-treatment systems and to project future needs for this important technology.

Legal Requirements

Current legal requirements for wastewater treatment date back to 1972, when major amendments were made to the Clean Water Act. This federal legislation existed before 1972, but was amended in a very major way in 1972 to require sweeping changes in wastewater treatment in all 50 states and territories. Prior to 1972, wastewater treatment was required only when there was a demonstrated need for it—a lake or natural resource would be spoiled, or some economic asset, such as a city's drinking water supply, would be corrupted.

Under these circumstances some form of wastewater treatment was usually required, and local or state agencies set standards, often called stream standards. The federal government became involved only in the case of disputes or the failure of local governments. Stream standards were designed to protect the natural resource in the most economical fashion, by requiring the least treatment to prevent degradation of water quality. Disputes were especially common when wastewaters crossed state boundaries. This situation was unacceptable and more time and money were spent arguing about treatment than actually treating wastewaters (a similar problem exists with the Superfund activities of the 1980s and 1990s). The near-destruction of Lake Erie and other important natural resources are examples of the failure of this method of regulation.

Everything changed in 1972, with the federal government enacting source standards. The post-1972 rules require a minimum of secondary wastewater treatment, even if the receiving water does not require secondary treatment for its protection (treatment methods will be defined later). Stream standards still exist for very sensitive receiving waters, which may need advanced treatment for protection.

This sweeping legislation changed almost everything about the way cities and industries made wastewater-treatment decisions. No longer could they demonstrate nondegradation of the receiving water to

This picture shows the Hyperion Wastewater Treatment Plant. It is the City of Los Angeles' oldest and largest treatment plant. The first construction dates back to the early part of this century. Partial secondary treatment (100 million gallons per day, or MGD) was added in 1955 for water reclamation; however, it was not until 1994 that significant amounts of reclamation began. In the background is the Scattergood power plant (red smokestacks) where excess anaerobic digester gas is burned to manufacture electricity. The circular tanks in the background and the light-colored tanks to their left make up the first part of the new plant. This first part can treat 200 MGD. It uses high-purity oxygen (HPO) instead of atmospheric oxygen. This technology is generally more expensive but requires less land, which is at a premium at Hyperion. The dark-colored rectangular tanks in the middle and left front of the picture are parts of the old secondary plant. The old plant was rated at 100 MGD and later upgraded to 180 MGD. It is obvious that the newer HPO technology uses less land area. Pacific Coast Highway is visible on the right side of the picture. The old secondary plant was demolished to make room for the second phase of the new construction and sludge-processing facilities.

avoid secondary wastewater treatment. Secondary treatment was required in all cases. This presented a special problem or concern for Southern California, where many local government officials believed that secondary treatment would never be required. Here the ocean floor rapidly slopes downward, and it is possible for a treatment system to discharge into very deep water by constructing an effluent pipeline only a few miles in length. Major West Coast cities lobbied Congress to change the 1972 legislation to exempt them from secondary treatment. In 1977 the Clean Water Act was amended again, and a provision was included that allowed West Coast cities to request a waiver from secondary treatment, if they could demonstrate that the wastewater discharges would not damage the ocean. The U.S. EPA was charged with the responsibility to approve the waiver request. Many West Coast treatment agencies applied for the waiver, and only in the last several years have most of the appeals been denied. Therefore, several major agencies, such as the City of Los Angeles and the Los Angeles County Sanitation Districts, are only now constructing secondary wastewater treatment facilities that were mandated by Congress in 1972.

These laws and regulations, the need for environmental protection, and water reclamation, which was not envisioned in 1972, are motivations for providing wastewater treatment. These factors create the varying levels of treatment found in Southern California and will dictate how treatment plants are constructed and improved in the future.

Water Quality

Water quality is measured by many different parameters, and as we develop better methods of measurement, we find new and different pollutants in waters and wastewaters. Potable water may be the purest substance any of us will ever experience. In the 1950s and 1960s, a major manufacturer advertised its soap as being "99 $\frac{44}{100}$ percent pure." Wastewaters that are only this pure would be very contaminated waters. The average potable water supply is more than 99.95 percent pure and domestic wastewaters are usu-

The average household produces 60 gallons of wastewater per day per person. Approximately 70 percent of the potable water used in a household becomes wastewater.

This picture shows the anaerobic digesters at Hyperion. The egg-shaped digesters are the new construction. The conventional digesters are visible on the right side of the picture, between groups of egg-shaped digesters. Dockweiler Beach is visible in the background. Early in the history of the Hyperion treatment plant a number of important development studies were performed. Most notable among these was the first full-scale use of thermophilic anaerobic digestion. The secondary plant is visible in the background, beyond the buildings that appear at the back of the picture.

ally in excess of 99.8 percent pure. For this reason, we generally discuss the contaminants in water as opposed to the purity of the water. Contaminants are indicated as parts per million (1 weight of a contaminant to 1 million weights of the water-contaminant mixture) or parts per billion, parts per trillion, etc. More recently, we describe contaminants as concentrations, such as milligrams per liter (mg/L), micrograms per liter (ug/L), etc.

Wastewaters contain many types of contaminants or pollutants. Dissolved solids are the most abundant contaminants. Dissolved solids are primarily composed of various salts, such as sodium chloride—common table salt—and calcium carbonate, which is related to water hardness. Among other things, they form the white scale on the bottom of a coffeepot. Fortunately, in most cases, dissolved solids are not harmful to humans or aquatic life. Therefore, few treatment plants are designed to remove dissolved solids, which establishes an important principle of water and wastewater treatment. Treatment plants are designed only to remove contaminants that are harmful; the plant does not generally treat other contaminants. Dissolved solids are characterized by a laboratory procedure called total dissolved solids, or TDS.

The most important class of wastewater contaminants are compounds that react with oxygen. The classic fish kills of the first half of this century are the result of this class of pollutant. Oxygen-demanding contaminants include organic substances such as carbohydrates (e.g., common sugar) and proteins. Most people are startled to learn that such a common and harmless substance as sugar can be such an important water pollutant. The reason for this importance is the need to maintain dissolved oxygen (DO) in receiving waters.

Receiving waters contain many types of aquatic life. Virtually all life that we associate with unpolluted water requires dissolved oxygen for respiration. Fish, crustaceans and plankton all require DO. The loss of DO invariably results in massive changes in the water's ecology, such as fish kills. The absence of DO, or anaerobic conditions, results in unsightly and odorous conditions. For these reasons, the earliest treatment plants were designed to remove oxygen-demanding material, and this is still the most important function of a domestic wastewater treatment plant. Oxygen-demanding pollutants are characterized by various laboratory procedures, such as the biochemical oxygen-demand (BOD) test.

The second most important class of pollutant for wastewater treatment plants to remove is suspended solids (TSS). Suspended solids are composed of colloidal

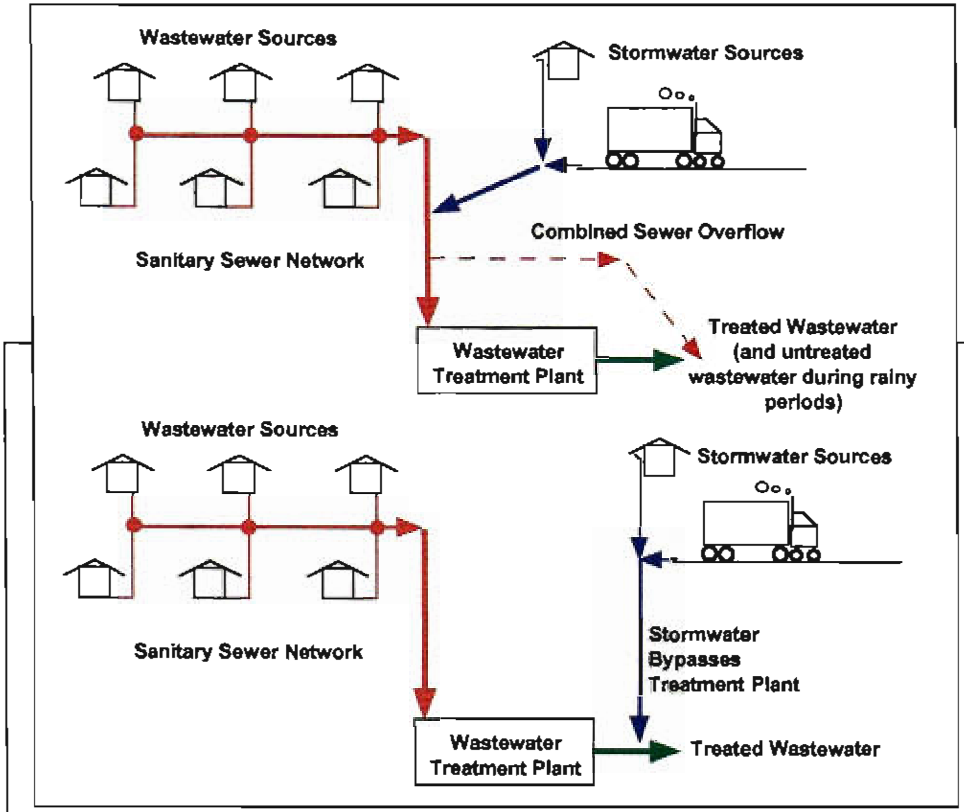


FIGURE 1: Schematic Diagram of Combined (top) and Separate Sewer Systems (bottom)

and particulate material. In a glass of water, they may appear as discrete particles to the human eye, or they may create color and a murky appearance. Suspended solids may break down into oxygen-demanding contaminants and they may change the ecology of receiving water by reducing sunlight penetration, or settling and covering the bottom. Suspended solids are measured by filtering a sample and are reported as TSS.

It may surprise the reader to learn that treatment plants for the major part of this century were designed almost entirely to remove BOD and TSS. These pollutants, along with major nutrients (nitrogen and phosphorous), are often called conventional pollutants. Exotic pollutants, such as heavy metals, carcinogens, toxins and bioaccumulating contaminants, were not explicitly considered in treatment-plant design until very recently. We now know that these contaminants are important, and new treatment and pollution-prevention techniques are used to control them.

Wastewater Treatment

We will now discuss wastewater-treatment systems in a more complete way. The first part of the system is the collection system, or sewer system. There are two types of systems: combined and separate. Figure 1 schematically shows the differences. Combined sewer systems collect both sanitary wastewater and stormwater. Separate systems have one set of sewers reserved for sanitary waste and a second set, often called a drain rather than a sewer, for stormwater. Most modern cities have separate systems, while older cities have combined systems. Most areas in Southern California have separate sewer systems. Many East Coast cities and some West Coast cities (e.g., parts of San Francisco) have combined systems.

At first it may seem more desirable to have combined systems, so that both stormwater and wastewater are treated. The actual situation is different. Stormwater runoff from even a small rain is usually many times as great as normal wastewater flow. Figure 1 (top) shows a "combined sewer overflow," or CSO. During large rains, wastewater and stormwater overflows bypass the wastewater treatment plant and enter the environment without treatment. Such overflows haunt many East Coast cities and routinely result in raw sewage spills. It is extremely expensive to control CSOs; the Metropolitan Sanitary District of Greater Chicago spent billions of dollars to build many large, underground storage tanks

Most modern cities have separate sewer systems, while older cities have combined sewer systems. Combined systems must bypass raw wastewater during heavy rains.

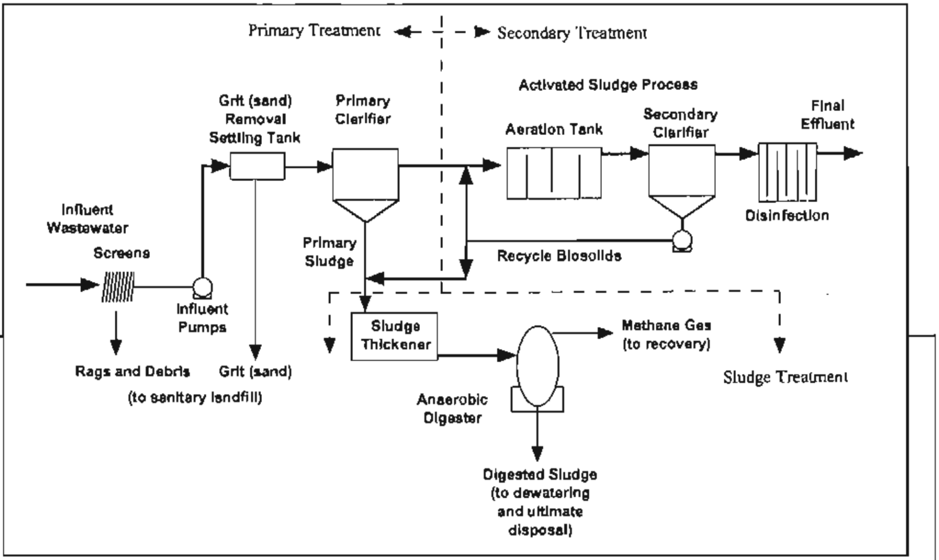


FIGURE 2: Typical Secondary Wastewater Treatment Plant with Disinfection

(deep tunnels) to control CSOs.

Southern Californians are fortunate to have separate sewers. The only disadvantage is that the small flow in storm drains during dry weather is not treated. This small flow, called urban runoff, results from landscape irrigation, cooling tower and condensate discharge, groundwater seepage and, unfortunately, illegal discharges. At present, these small flows are discharged at the shoreline and create unsightly and sometimes unhealthful conditions. Many of these small flows are being diverted to sanitary sewers using Proposition A funds. The diversion is "smart"; during low flow, runoff is directed to the treatment plant, but during storms or high flow, the stormwater is sent directly to the ocean. The magnitude of the pollutants transported to the ocean by urban runoff will be discussed in future Report Cards.

Wastewater-treatment plants have varying designs, but all can be classified using categories of primary, secondary and tertiary treatment. Secondary treatment has a legal definition, since it is required by the Clean Water Act. Primary treatment plants remove 30 to 40 percent of the BOD and 50 to 60 percent of the TSS. Secondary plants must remove either 85 percent of the BOD and TSS, or to a concentration of 30 mg/L each, whichever is less. Figure 2 shows a typical wastewater treatment plant with effluent disinfection.

Influent wastewater is first coarse-screened (e.g., 0.5- to 2-inch openings) and is then pumped to the rest of the treatment plant. The screens remove rags and protect the pumps from debris in the wastewater (at large treatment plants, especially those with combined sewers, automobiles and other large objects are occasionally found in the raw wastewater!). Sand particles, called grit, are removed next. The particles are inorganic, cannot be treated in the rest of the treatment plant, and may harm the plant. The grit is removed in a sedimentation tank. The grit and rags are usually hauled to a sanitary landfill. The next process is a primary clarifier. The primary clarifier is a large, quiescent tank, and suspended solids are allowed to settle to the tank bottom. The wastewater is allowed to remain in the tank for as much as two hours. Large particles with density greater than water density will settle and are removed from the tank bottom as sludge. Oil and grease are skimmed from the tank surface (not shown). The clarified effluent is called primary effluent. This partially treated effluent is still very pathogenic and can contain chemicals that are toxic to humans and harmful to the receiving water. The treated water would look cloudy in appearance and would have a distinct odor.

At secondary treatment plants, the primary effluent is further treated in a biological process, such as the activated sludge process. The activated sludge process and its variants are the most commonly used secondary processes for medium-to-large treatment plants. In the process, a special consortium of bacteria and other microorganisms are grown. They metabolize the pollutants as they grow. This removes the

Methane gas can be produced at most treatment plants, which can be used to generate electricity to operate a large part of the plant.

BOD and TSS and can detoxify many pollutants and adsorb others. The secondary process removes at least 85 percent of the BOD and TSS, and well-designed and operated plants may remove 95 percent of the BOD and TSS. The effluent is clear with only a few pinhead-size suspended solids. It is not potable and still contains pathogens; it may contain trace metals and hard-to-treat organic compounds, such as pesticides. Nevertheless, it is usually suitable to discharge into many receiving waters.

Figure 2 also shows the treatment system for solids, or sludge. Primary sludge and waste-activated biosolids are thickened and then treated in an anaerobic digester. The digester produces methane, which is often used in the plant for heating and generating electricity. In some very large plants the excess gas is sent to a commercial power plant for recovery. The sludge-processing parts of the treatment plant can be the most expensive to operate and are usually the most troublesome. Odors are expensive to control and maintenance requirements are high.

Tertiary treatment is not shown in Figure 2 and can take on many forms and types. Filtration, carbon adsorption, reverse osmosis and ion exchange are several options. It is easy with today's technology, although somewhat expensive, to treat secondary effluents to levels that are much better than potable-water requirements. Demonstration projects at San Diego, Lake Arrowhead and other places have shown that it is possible to reliably treat secondary effluents so that indirect potable reclamation can be performed.

This section has described several important concepts that are necessary to understand the other material in this article as well as later articles that are being planned. Important concepts are separate/combined sewers; stormwater and wastewater; treatment to remove only the harmful contaminants; primary, secondary and tertiary treatment; conventional pollutants; and CSOs.

Major Southern California Agencies and Treatment Networks

There are several large agencies that provide wastewater treatment in Southern California. The City of Los Angeles has a separate collection system and operates one large and three smaller treatment plants. The city's treatment system is independent from the system operated by the Sanitation Districts of Los Angeles County, which also has a separate collection system and operates one very large plant and 10 smaller plants. Orange County also operates three treatment plants. These three agencies operate in a similar fashion with similar technologies. The plants are operated as a network, with a large coastal plant and smaller upstream plants, most of which are hydraulically linked with the coastal plant. By clever use of the sewers, it is possible to use the coastal plants for the majority of the sludge-treatment, which makes the upstream plants simpler to operate and frees them from odorous sludge-treatment processes. Figure 3 shows how this network functions and is representative of all the agencies.

The system is composed of several trunk sewers (only one shown for clarity), one or more inland plants, which is often a water reclamation plant (again, only one shown), a coastal plant, and an ocean outfall (6). Wastewaters are produced throughout the service area, but industrial wastewaters are generally produced in the coastal areas and discharged to sewers close to the coastal plants. As the area has grown in population, the capacity in the trunk sewers has been consumed. One way to restore capacity is to construct additional or larger sewers. An alternative

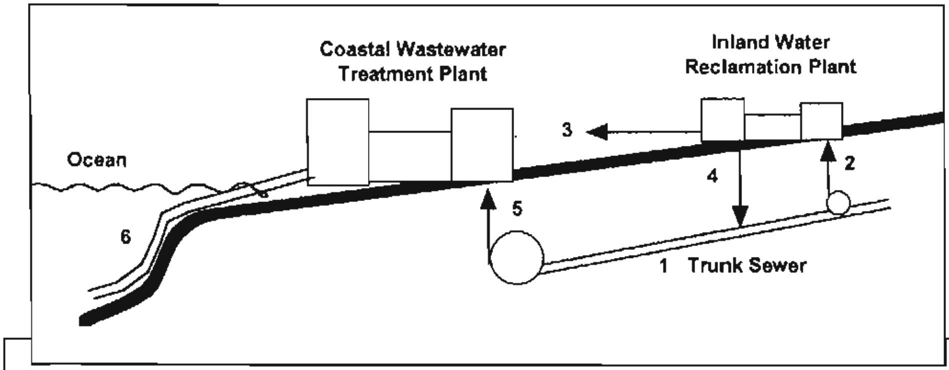


FIGURE 3: Schematic of the Treatment Plant Network Concept

method, which has been employed throughout Southern California, is to build the inland treatment plants. The inland plant removes a specified quantity of wastewater from the trunk sewer, restoring its capacity. The wastewater is treated to the required standard, generally beyond secondary treatment, and discharged (3) to inland waterways or reclaimed for industrial purposes or for groundwater recharge. The sludges produced during treatment, both primary and secondary, are returned to the trunk sewer (4). The volume of the sludges is usually only 1 percent or less of the treated wastewater, and there is ample capacity in the sewer. The coastal plant receives both raw wastewaters as well as sludges from the inland plants (5). The coastal plant treats the wastewater to the required standard (generally less than secondary at present, but changing to secondary as soon as existing construction is completed), and has sufficient sludge-treatment capacity to treat all the sludges. Treated wastewater is discharged several miles out into the ocean, usually at depths of more than 100 meters (6).

The topography of our area is such that very long gravity sewers can be constructed, so that the wastewaters flow to the coastal plant without pumping. Therefore, returning the sludges to the sewer does not interfere with pumping. The advantage of this technique is that the inland plants do not require sludge-disposal facilities. Most of the sludge-treatment facilities are located at the coastal plants, where economies of scale are available. A second advantage of this treatment technique is that industries are generally located near the coastal plants, which means the inland plants are freer from industrial wastewaters. Therefore, it is easier to treat wastewaters at the inland plants, and the effluents are freer of toxic or hard-to-treat contaminants. A third advantage is that the flow rate of one inland plant can be temporarily increased to allow reduced flow at another plant for maintenance.

As wastewater flows increase due to growth, planners have several alternatives. They can increase the capacity at the coastal plant and benefit from the economy of scale and less treatment objective, but produce no reclaimed water or restored sewer capacity. Alternatively, a new inland plant can be created or the capacity of an existing plant can be increased. This alternative requires higher treatment efficiency due to the stream standards, but can produce reclaimed water and can increase sewer capacity.

How Well Are We Doing?

This article so far has provided background on sewer and treatment systems. We now can begin to discuss how well we are doing and what goals we might set for the future. The first question relates to secondary treatment.

Congress mandated secondary treatment in 1972. So why is it that we still are not performing secondary treatment at our coastal plants? The agencies responsible for wastewater treatment delayed treatment-plant construction in the hopes of obtaining ocean waivers. They believed that the environmental degradation caused by primary effluent in the ocean was less than the environmental and social cost of providing full secondary treatment. There are issues in favor of and against this belief.

Secondary treatment involves significant cost. Many of us can review our water bills to see some of this cost. The rebuild-

Partially treated wastewater discharges have covered the ocean floor in many areas with sludge blankets as much as a meter thick. The sludge blankets contain pollutants whose potential impacts were largely undocumented at the time of their discharge.

ing of the Hyperion wastewater treatment plant, with its sludge-processing facilities, is a multibillion-dollar investment and has significant operating costs. Secondary treatment also produces large quantities of sludge, which must be treated and disposed of in an environmentally safe fashion. In many areas, sludges are incinerated, which is not possible here due to our air quality concerns. Dewatered sludges can be disposed of in landfills, which are already oversubscribed in Southern California. We recycle some of the sludges in soil amendments, but there is too little market to dispose of all our sludges.

The environmental impact of not providing secondary treatment is also significant. The wastewater discharges have covered the ocean floor in many areas with sludge blankets more than a meter thick. These sludge blankets have dramatically changed the ecology of these areas and resulted in other side effects. Various pollutants have been implicated in fish diseases. The sludge blankets contain pollutants whose potential effects were largely unknown at the time of their discharge. Many will eventually be reintroduced into the environment with unknown impacts. One in particular, DDT, which is present in major quantities in the sediments off Palos Verdes, has already had significant impact on the ocean ecology.

Part of the dilemma of providing secondary treatment relates to our improved understanding of the impacts of pollutants on the environment. In 1972, when Congress made major modifications of the Clean Water Act, oxygen-demanding materials were the major pollutants in wastewater. Congress was correct in addressing these pollutants, but decisions made today must include other considerations. The decision today must be made on new criteria—the impacts of toxins, such as heavy metals and polynuclear aromatic hydrocarbons, and pathogens on the environment. Some of these materials accumulate in the food chain and have impacts on fish, birds and mammals. It is no longer adequate to base treatment decisions on the simplistic definitions of secondary treatment.

The City of Los Angeles and the Sanitation Districts of Los Angeles County lost their legal battles for ocean waivers. Both agencies are expanding their ocean plants to provide full secondary treatment. The city is well under way and should be finished by 2000. The county should be complete by 2002. They lost their battles not on the basis of removal of BOD or TSS, but on the basis of the impacts of other pollutants. Orange County has an ocean waiver and there are no plans at present to expand secondary treatment.

One can ask the question about the impact of the delay in constructing secondary plants. There were obvious cost savings because we have not had to pay for the operation of the plants, and dispose of the extra sludge. Losses include the loss of grant money (in the early days of the grant program, the federal government paid 75 percent of the construction cost of new plants), as well as the environmental degradation of the ocean. Another cost, which is less well-known, is the additional construction cost created by trying to "catch up." It is more expensive to rush the construction of treatment facilities. The multimillion-dollar failures of innovative sludge-treatment systems, such as the Hyperion Energy Recovery System, are examples.

The Future

We no longer need to debate the wisdom of secondary treatment in Los Angeles County. We are well on our way to upgrading our treatment plants. But there are other important questions.

The first relates to water reclamation. We are finding that it is simply too expensive to throw away the treated wastewaters by discharging them into the ocean. With limited additional treatment, such as filtration or reverse osmosis, these wastewaters can be reclaimed and used for a variety of purposes. Plans are under way to recover as much as 25 percent of the Hyperion effluent. Inland reclamation plants are being expanded with increased capacity, as well as additional treatment methods. The question of ocean discharge will decline in importance as we reclaim more and more of our treated wastewaters.

A second issue relates to stormwater. Figure 1 shows both stormwater and wastewaters. We have traditionally thought that stormwaters are clean. We are now finding that stormwaters transport contaminants such as pathogens, heavy metals, hydrocarbons, toxins and bioaccumulating contaminants to the ocean. More importantly, storm drains discharge at the beach, where human contact is likely. Our analysis indicates that contributions to Santa Monica Bay from stormwater is or will be greater than from treated wastewaters. After we obtain full secondary treatment, we must practice better stormwater management to reduce emissions to Santa Monica Bay. Future Report Cards will report on stormwaters.

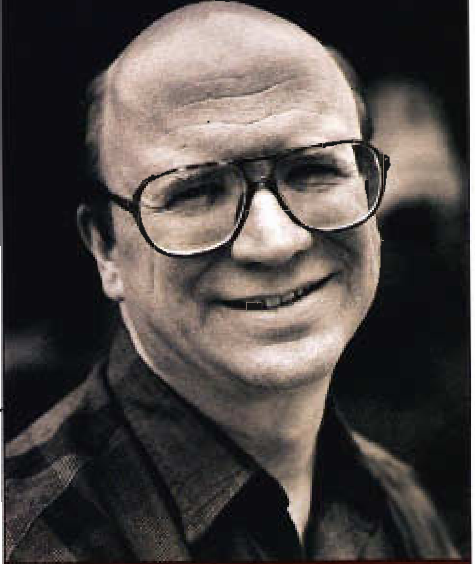
Grade

There are several ways we must grade ourselves on wastewater treatment:

Inland Plants: A. If we evaluate our inland water reclamation plants, we have a good report. We built them early and they are operated well and economically. The regulatory agencies did not have to drag our treatment agencies, screaming and kicking, into new construction programs.

Coastal Plants: C. If we look to our coastal plants, the grade is not so good. We expect to complete construction about 25 years after Congress' original deadline. (Boston will complete its plants at about the same time.) We chose the wrong strategy—our treatment agencies fought the U.S. EPA and lost on the basis of environmental impacts. We are lucky to get a C. Our worst grade is for allowing the deterioration of the Hyperion treatment plant in the early '80s, where we fail.

This article provides background and a frame of reference for following articles. Stormwater and water-reclamation articles are being planned.



Michael K. Stenstrom has been a professor in the Civil and Environmental Engineering Department for 21 years. During this time he has performed research and teaching in the areas of water and wastewater treatment. He is particularly interested in oxygen transfer, degradation of specific organic compounds and applications of control systems to biological processes. In the past several years he has worked on stormwater management. In this area he has developed a mass emissions model of stormwater-transported pollutants to Santa Monica Bay, and evaluated several best management practices for minimizing stormwater pollution.

Professor Stenstrom received his Ph.D. from Clemson University in 1976 and worked two years in industry before joining UCLA in 1977. He currently serves as chair of the Civil and Environmental Engineering Department. He has written more than 100 scientific publications and received more than $10 million in grants and contracts. He also serves as a consultant to municipalities and industries that wish to improve their treatment systems.

While human civilization has made extraordinary social and technological strides during the past century, **too often the environment has been sacrificed for profit or convenience.** Accordingly, although such progress has improved the quality of life for some, it has resulted in a serious deterioration of the planet's water, land and air resources, thus jeopardizing the future quality of life for all.

on various aspects of environmental science, technology and policy, the Institute of the Environment mobilizes these diverse resources through a variety of unique programs. The Institute's Los Angeles Basin Watershed Project is integrating all of the aspects of water quality, availability and management—from meteorology to hydrology to coastal oceanography—for the Los Angeles region. In a similar way, the Institute's Airshed Project is addressing one of the major plagues of Los Angeles and other sprawling urban areas—air pollution and its impacts on human health. To ensure that relevant information is readily available to planners and to the public, the Institute is also compiling one of the largest and most diverse environmental Geographical Information Systems (GIS) for a major urban area, providing the campus and community with access to an invaluable source of information. Finally, this Southern California Report Card on the Environment is designed to summarize and evaluate the progress made in protecting the regional environment and maintaining environmental quality.

Reaching Toward a Livable World

While human civilization has made extraordinary social and technological strides during the past century, too often the environment has been sacrificed for profit or convenience. Accordingly, although such progress has improved the quality of life for some, it has resulted in a serious deterioration of the planet's water, land and air resources, thus jeopardizing the future quality of life for all. The UCLA Institute of the Environment seeks to identify, understand, and ultimately provide solutions for problems that threaten our environmental future. The Institute seeks practical approaches, in view of the needs of a diverse community, and is committed to developing fundamental knowledge and trained minds to lead us into the next millennium.

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